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If various color names are printed in various color inks, an observer has great difficulty in rapidly naming the ink colors (Stroop Color Word Test) unless the color names and the ink colors are mutually reinforcing, or the color names are unknown to the observer. The latter suggests a partial measure of second-language fluency; the feasibility of which was examined by administering a bilingual version of the color word test to four groups of four college students each whose familarity with French differed. Results showed that when the color names are French and the subject names the ink colors in English, greater familiarity with French is associated with greater interference in naming. However differences between the groups in average naming time were not statistically significant.

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FOREIGN LANGUAGE EXPERIENCE AND COLOR WORD INTERFERENCE[1]

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If various color names are printed in various color inks an observer has great difficulty in rapidly naming the ink colors (Stroop Color Word Test) unless the color names and the ink colors are mutually reinforcing, or the color names are unknown to the observer. The latter suggests a partial measure of second-language fluency, the feasibility of which was examined by administering a bilingual version of the color word test to 4 college student groups whose familiarity with French differed. As might be expected, when the color names are French and the subject names the ink colors in English, greater familiarity with French is associated with greater interference in naming; however, differences between the groups in average naming time were not statistically significant.

The Stroop color word test presents subjects with a conflict situation in which they must state aloud the color of the ink used to print a series of color words on a card. Interference arises from the fact that the word and the ink color both vary, but are always incongruent (CW). Performance time in this situation under conditions of set intended to elicit rapid, accurate performance is compared with the time it takes to perform two related tasks under the same set conditions, i.e., in one task, subjects read a similar series of color words printed in black (W); in the other task, subjects name patches of color (C). Although there is no standard test with respect to materials, administration, or scoring, there is remarkable uniformity among the published findings. Without exception, investigators report that times are faster for W cards, somewhat slower for C cards, and appreciably slower for CW cards.

Differences between scores are affected by a host of variables, including practice, vividness and dissimilarity of colors, length of rows of items, age and sex of subjects, and several other factors discussed at length in a recent review (Jensen & Rohwer, 1966). Included in the review are evaluations of the methods used for administering the test, as well as recommendations for an improved and standardized form of the test. These recommendations were taken into consideration in conducting the present experiment which employed the Stroop Color Word Test

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to measure the extent of interference experienced by individuals, varying in degrees of familiarity with the French language, when they were required to give the English name of the ink color in which French color words were printed.

The study was prompted by Lambert's investigations (1967) in which balanced and non-balanced, compound and coordinate French-English bilinguals were required to name the ink color of French color words, English color words, and non-color words in both languages under a set for both speed and accuracy. Among other results, Lambert reports that, with color words similar to those used in this experiment, interference is less when the language in which subjects name the colors differs from the language in which the color names are printed. Further, when the subjects are native speakers of English studying French, interference is less when the response language is English and the interfering language is French. Lambert's series of experiments led to speculation that the degree of interference may be directly related to the level of familiarity with the interfering language.

Accordingly, if subjects with varying experience with the French language are asked to name the colors in which a group of French color words are incongruously printed, we may expect that the subjects with no familiarity with French will perform the task fastest, subjects with limited familiarity with French will take longer, subjects with extensive familiarity with French will take even longer, and native speakers of French (albeit fluent in English) will require the longest time of all. The present study evaluates these expectations, hence the value of the bilingual Stroop test as an index of second language familiarity.

Materials

The three types of cards used were prepared with commercially available Carter's Extra Service Felt Stamp Pads, and rubber stamps of elite size type. Since stamp pad inks did not contrast well with the black background recommended by Jensen and Rohwer for its "aesthetically more striking appearance" it was decided to use white-non-glossy card stock cut to 4 1/2" x 6" dimensions. All frequent English color words were considered for use in this study, but only four satisfied these two requirements: (a) the color is available as a stamp-pad ink color, contrasting well with a white background, and (b) the English color name has a phonemically and orthographically dissimilar French translation-equivalent. The four French-English pairs of color words selected were vert-green, rouge-red, noir-black, and mauve-purple. Evidently we were constrained to use several French words with some currency in English.

Each card type consisted of six rows with eight elements each. The words and colors used on the various cards were systematically varied to insure that all possible sequences of color words and inks occurred an equal number of times within the series, that no color word or ink was adjacent to itself in any of the rows or columns on any of the cards. The C cards consisted of 1/4" diameter circular dots made with an unblemished standard pencil eraser and the stamp pads described above. The format of a typical C card is shown in Figure 1. The model in Figure 2 is representative of the CW cards which were prepared using the stamp pads and rubber stamps. The W cards were identical with the CW cards in format except that English color words were used and were typed in black ink. (Figure 3)

Insert Figures 1, 2, and 3 about here

Procedure

Sixteen subjects were selected from University of Michigan undergraduate and graduate students: four had no experience in French or any other Romance language; four were in the second semester of college French; four were senior French majors who had spent the previous year studying in a French university; and four were native speakers of French whose second language was English. All subjects were unpaid volunteers.

The test was administered to each subject separately under nearly identical conditions. Each subject was seated at a desk in a room illuminated only by a Tensor lamp (model 5975, output 8.1 O.C.U. 29 V.A.). The lamp was focused on the various exposed cards. Each subject familiarized himself with an example of the test cards while the instructions quoted below were read to him. Any questions were answered by re-reading the instructions. The performance of each subject in each phase of the test was measured using a card he had not seen. The selection of the particular card with which a subject was tested was made randomly and independently except that in order to minimize possible sequential practice effects, all the cards presented to any one subject contained different response sequences. The order of card presentation was W, C, CW, CW, W and the following instructions were read in the order given. (Instructions for first W card)

> "During the first part of the experiment, you are to read aloud a paragraph like this one containing a series of four words: red, black, purple, and green. Read as rapidly as you can, since you will be timed. At the same time, do not make any mistakes as they will count against you. Do you have any questions?"

(Instructions for the C card)

"Now I am going to show you a card like this one on which there is a series of colored dots. I want you to state aloud the color of the dots as quickly as you possibly can without making any mistakes. The dots are either red, green, black or purple. Do you have any questions?"

(Instructions for the CW card)

"Next I am going to show you a card similar to this one, on which there is a series of four French words printed many times in either red, purple, green, or black. As you can see, the words are vert, rouge, mauve, and noir. You are to name the color of the ink in which each word is printed. If the French word is printed in green ink, say 'green', in purple ink, say 'purple', etc. Remember to work quickly as possible while avoiding mistakes. Are there any questions?"

(Instructions for the second W card)

"Now you will repeat the first part of the experiment by reading out loud a paragraph of English color words. Once again, you will be timed and mistakes will count against you. Do you have any questions?"

Results

The performance time in seconds for each subject in individual tasks, together with the group means and standard deviations are presented in Table 1. The mean

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Insert Table 1 about here

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performance times for the repeated tasks (W and CW cards) are indicated in columns $\bar{X}_w$ and $\bar{X}_{cw}$. Overall means by group by task are shown in Figure 4. Mean W card

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Insert Figure 4 about here

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time seems fairly uniform for all groups, mean C card time for Group IV is somewhat higher than for the other groups, and mean CW card time rises as a result of the degree of familiarity with the French language. In addition, the group rank of each subject for each test shown in Table 2 indicates a general consistency of performance across all tasks.

Insert Table 2 about here

A two-way analysis of variance was performed for groups and tasks with the latter highly significant ($F = 77$, $df = 4, 48$, $p << .01$). No scores violated the general observation of this and earlier studies that performance time increases

from performance on W cards, through C cards to CW cards. The effect of groups is significant ($F = 4.0$, $df = 3, 12$, $p << .05$) as is the interaction ($F = 3.6$, $df = 58, 16$, $p << .01$). Most of the intergroup difference found seems to lie among the scores received on the C cards and CW cards. The scores on all three tasks were analyzed with the following results.

No statistically significant difference exists among group times on W cards, either during or between the first or second exposure to them; however, the scores for Group IV are slightly higher on the average than those for the other groups. It is interesting to note that both Groups III and IV exhibit increased performance times during the second exposure to W cards, (W_5) which took place after the C and CW cards.

There is a statistically significant difference between the C card mean for Group IV and the C card mean for the other three groups combined. There is an

$$[p(|t_{14_o}| \geq 6.15) < p(|t_{14}| \geq 2.98) = .01 = \alpha]$$

analogous difference between these groups with respect to CW card performance times.

$$[p(|t_{30_o}| \geq 4.53) < p(|t_{30}| \geq 2.75) = .01 = \alpha]$$

Jensen (1965) evaluated the 11 formulas for deriving scores from the Stroop test that have been reported in the more than 60 published psychological studies in order to determine their reliability. A large group (N = 386) of undergraduate students in an introductory educational psychology course (University of California) was tested on two occasions and another group (N = 50) was tested on 10 occasions, separated by at least one day. All the data were scored with each of the formulas, and all of the derived scores were intercorrelated and subjected to multivariate analysis. The conclusion of the study was that only three factors account for all variances among the derived Stroop scores. Factor I, represented by the formula C/C + W, is a measure of individual differences in the degree of difficulty subjects have in naming colors with the "speed" factor, i.e., speed of reading words partialed out. Factor II, whose formula is CW-C, is the interference factor indicating the increment of difficulty of color-naming introduced by the conflicting color words. Factor III is clearly represented by the raw time score on the W card and represents the reading speed factor.

These three factors were applied to the scores collected in this experiment and analyzed for significance. The W card scores (Factor III) are not significantly different among the four groups. The group scores on Factor II are presented in Table 3 together with means, variances, and standard deviations.

Insert Table 3 about here

These data show a sharp division between the scores for Group I and the scores for the other three groups which is statistically significant.

$$[p(|t_{30_o}| \geq 3.01) < p(|t_{30}| \geq 2.98 = .01 = \alpha]$$

Table 4 shows the group scores derived for the computation of Factor I, the color-naming factor. The differences between the mean score for Group IV and the mean score for the other three groups is also significant.

$$[p(|t_{14_o}| \geq 5.48 > p(|t_{14}| \geq 2.98) = .01 = \alpha]$$

Insert Table 4 about here

Discussion

On the basis of previous studies that investigated the differences in the magnitude of the interference effect when the words printed in varying colors were nonsense syllables and non-color words, it was anticipated that the overall effect of presenting French color words to subjects with varying amounts of experience with the French language would be large enough to override the effect of differences among subjects with respect to age, reading speed, and color naming speed. In fact, variations in the performance time on the several tasks were so great that statistically significant differences among all the groups with respect to CW card performance times were impossible to obtain, although there is a significant difference between the mean CW performance time of Group IV, native speakers of French and the mean for the other three groups. Probably matching on the variables mentioned would reduce substantially the intragroup variance.

Although the French subjects probably had less experience with reading English aloud than the subjects of the other three groups, it was expected that all groups would be fairly uniform with respect to performance on the W cards. Table 1, however, shows a curious split among the mean performance times for the W cards, which separates these times into two groups--an "American" group consisting of Groups I and II and Group III before its exposure to the French conflict cards, and a "French" group consisting of Group III after exposure to French and Group IV. It is interesting to speculate whether the sudden plunge into a situation which tends to provoke thinking in French has the effect of inhibiting performance in English for those subjects with the greatest French language experience.

For Groups I and II, the CW cards may well be more or less analogous to the nonsense syllable and/or non-color word cards used in earlier studies (Klein, 1964; Lambert & Preston, 1967; Schiller, 1966). Such cards were the source of much less conflict than standard CW cards as measured by Factor II. If experiencing conflict has any effect on subsequent performance on W cards, it is more reasonable to assume that Groups III and IV would demonstrate this than Groups I and II for whom French words may be akin to nonsense syllables.

It was anticipated that the C card task would pose a slightly more difficult problem for Group IV than for the other three groups. Either of two processes may be taking place: (a) the color patch may elicit the mediating response of a French color word for the compound bilinguals of Group IV which then has to be translated into English, or (b) the subjects who were strong coordinate bilinguals may simply have more difficulty bringing the English word to mind for the color-patch stimulus. Either of these two situations, a combination of them both, or other similar processes could explain the relatively slower performance of Group IV on this task. As no attempt was made to ascertain the degree to which these subjects were compound or coordinate bilinguals (Lambert & Preston, 1967), no resolution of this anomaly is immediately obvious. Although the performance time variance of Group IV on this task was large, difference between the means of native speakers of French and the native speaking of English was significant.

The differences among group CW card times are also large and in the predicted direction for both exposures to these cards. Again, intragroup variance and the small populations make it unlikely that every group will be significantly distinct when raw scores alone are statistically analyzed.

The analysis of the transformed scores making up Factors I and II reveals a significant difference between the American subjects and the French subjects in color-naming scores (Factor I). Furthermore, an inspection of the means and standard deviations of all the groups with respect to the Factor II scores of Table 3 indicates that all subjects with some knowledge of French experience increasing amounts of conflict between French color words and the ink color in which they are printed. The evidence for this conflict lies in the increasing CW card performance times and group variances as a result of extent of French language experience. The difference between those subjects who have been exposed to French and Group I manifests itself as much in the changing magnitude of the mean performance time as in group homogeneity.

Finally, it should be noted that the combination of response and interference language selected for this experiment (English and French respectively) occasioned the smallest amount of interference in the study reported by Lambert and Preston (1967). The fact that the differences across groups in CW card performance times are large and consistent indicates that in all likelihood, an expanded, more sophisticated version of this test with subjects matched on age, reading speed, and color-patch naming speed, would yield statistically significant CW card scores. Conceivably it could also have important pedagogical implications, particularly in the measurement of the extent to which students have truly acquired foreign language habits.

Summary

The results of studies in which the Stroop Color Word Test has been used with nonsense syllables and non-color words printed in varying ink colors has led to speculation that French color words presented to subjects with varying amounts of French language background would produce similar large-scale effects. Administration of this variant of the test produced results in the predicted direction, but failure to match subjects on the relevant variables of age, reading speed, and color-patch-naming speed made the significance of the results tenuous, except that native speakers of French are significantly slower in the two phases of the test in which color patches were named in English and the ink color of French color words were named in English. It is hypothesized that matched groups of subjects will exhibit significant differences in performance time on the French color word conflict cards and that the consistency of these differences will be useful pedagogically.

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Footnote

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Figure Captions

Fig. 1. C card format. The C cards consist of an 8 x 6 matrix of colored dots approximately 1/4" in diameter of either red, purple, green, or black stamp pad ink against a flat white background.

Fig. 2. CW card format. These cards consist of an 8 x 6 matrix of French color words (rouge, noir, mauve, and vert) prepared on a flat white background with standard stamp pad inks corresponding to the color words, but with each word printed in a conflicting color.

Fig. 3. W card format. These cards are similar to the CW cards except that all color words are typed in black.

Fig. 4. Group means in seconds for each of the tasks performed in a bilingual Stroop Color Card Test.

Table 1

Performance Times in the Three Phases of a Bilingual Stroop Test

	W_1	W_5	$\bar{X}_w$	C_2	CW_3	CW_4	$\bar{X}_{cw}$
Group I	18.9	19.5	19.2	24.3	33.2	30.3	31.8
	15.9	14.9	13.4	24.5	27.3	27.1	27.2
No French	14.8	15.1	15.0	21.0	28.5	26.5	27.5
Experience	15.4	15.4	15.4	20.0	21.1	24.8	22.9
$\bar{X}_1$	16.2	16.2	16.2	22.4	27.5	27.2	27.4
SD_1	1.6	1.9		2.0	4.3	2.0	
Group II	14.0	13.6	13.8	19.0	23.4	22.0	22.7
	17.5	17.5	17.5	21.2	36.0	34.5	35.3
One Year	16.5	16.5	16.5	20.2	34.0	27.0	30.5
of French	16.0	16.0	16.0	20.0	35.4	33.6	34.5
$\bar{X}_2$	16.0	15.9	16.0	20.1	32.2	29.3	30.8
SD_2	1.3	1.4		.1	5.1	5.1	
Group III	17.0	18.4	17.7	20.0	31.6	31.0	31.3
	17.0	18.0	17.5	22.9	50.0	43.0	46.5
French	13.0	15.6	14.3	20.4	21.0	23.0	22.0
Majors	19.0	22.0	20.5	21.9	34.0	39.0	36.5
$\bar{X}_3$	16.5	18.5	17.5	21.3	34.2	34.0	34.1
SD_3	2.2	2.3		1.2	10.4	7.7	
Group IV	20.7	20.0	20.3	42.5	60.0	62.0	61.0
	15.1	16.3	15.7	28.6	35.2	30.9	33.0
Native	17.9	17.3	17.6	30.5	42.8	44.8	43.8
French	18.1	20.2	19.1	31.0	44.9	45.2	45.0
$\bar{X}_4$	17.9	18.4	18.2	33.1	45.7	45.7	45.7
SD_4	2.0	1.7		5.5	9.0	11.0	

Individual performance times to the nearest .1 second by task for each subject. Subscripts indicate presentation order of tasks. W = English color word reading, $\bar{X}_w$ = Means for word tasks, C = Color patch naming task, CW = ink color naming task for French color words, $\bar{X}_{cw}$ = Mean for CW task. Task means, group means and standard deviations are presented.

Table 2

Rank Order by Task for the Three Phases of a Bilingual Stroop Test

	W_1	W_5	C_2	CW_3	CW_4
Group I	4	4	3	4	4
No French Experience	3	1	4	2	3
	1	2	1	3	2
	2	3	2	1	1
Group II	1	1	1	1	1
One Year of French	4	4	4	4	4
	3	3	3	2	2
	2	2	2	3	3
Group III	2.5	3	1	2	2
French Majors	2.5	2	4	4	4
	1	1	2	1	1
	4	4	3	3	3
Group IV	4	3	4	4	4
Native French	1	1	1	1	1
	2	2	2	2	2
	3	4	3	3	3

Rank order of subjects with respect to performance time on the three tasks of a bilingual Stroop Color Word Test. Subscripts indicate presentation order of tasks, W = English color word reading, C = Color patch naming task, CW = ink color naming task for French color words.

Table 3

Bilingual Stroop Test

Interference Factor Scores (CW-C),

Group Means, and Standard Deviations

	CW-C	Group Means, Variances, and Standard Deviations	
Group I No French Experience $\bar{X}_1$ SD_1	8.9 6.0 2.8 2.6 7.5 5.5 1.1 4.8	$\bar{X}_1 = 4.9$ $SD_1^2 = 6.1$ $SD_1 = 2.5$	
Group II One Year of French $\bar{X}_2$ SD_2	4.4 3.0 14.8 13.3 6.8 13.8 [illegible] 15.4	$\bar{X}_2 = 10.6$ $SD_2^2 = 22.2$ $SD_2 = 4.7$	$\bar{X}_{2,3,\&4} = 12.0$ $SD^2_{2,3,\&4} = 39.8$ $SD_{2,3,\&4} = 6.3$
Group III French Majors $\bar{X}_3$ SD_3	11.6 11.0 27.1 20.1 .6 2.6 12.1 17.1	$\bar{X}_3 = 12.8$ $SD_3^2 = 66.8$ $SD_3 = 8.2$	
Group IV Native French $\bar{X}_4$ SD_4	17.5 19.5 6.6 2.3 12.3 14.3 13.9 14.2	$\bar{X}_4 = 12.6$ $SD_4^2 = 27.6$ $SD_4 = 5.3$	

[illegible] difference between performance times to the nearest .1 sec. in two phases of the Stroop Color Word Test for four groups differing in French language experience. (CW = ink color naming of French color words, C = color patch naming). The mean performance times $\bar{X}$ variences SD^2 and standard deviations SD are indicated for each group and for Groups II, III, and IV combined.

Table 4

Bilingual Stroop Test Color-Naming Factor I Scores (C/CW), Group Means, Variances, and Standard Deviations.

Group I No French Experience $\bar{X}_1$ SD_1	.56 .61 .58 .56	$\bar{X}_1 = .58$ $SD_1^2 = .00042$ $SD = .020$
Group II One Year of French $\bar{X}_2$ SD_2	.58 .55 .55 .56	$\bar{X}_2 = .56$ $SD_1^2 = .00015$ $SD_2 = .012$
Group III French Majors $\bar{X}_3$ SD_3	.53 .57 .59 .52	$\bar{X}_3 = .55$ $SD_3^2 = .00082$ $SD_3 = .029$
Group IV Native French $\bar{X}_4$ SD_4	.68 .65 .63 .62	$\bar{X}_4 = .64$ $SD_4^2 = .00052$ $SD_4 = .023$

The ratio between performance time in the color patch naming task (C) and the ink color naming of French color words task of a bilingual Stroop Color Word Test (C/CW).

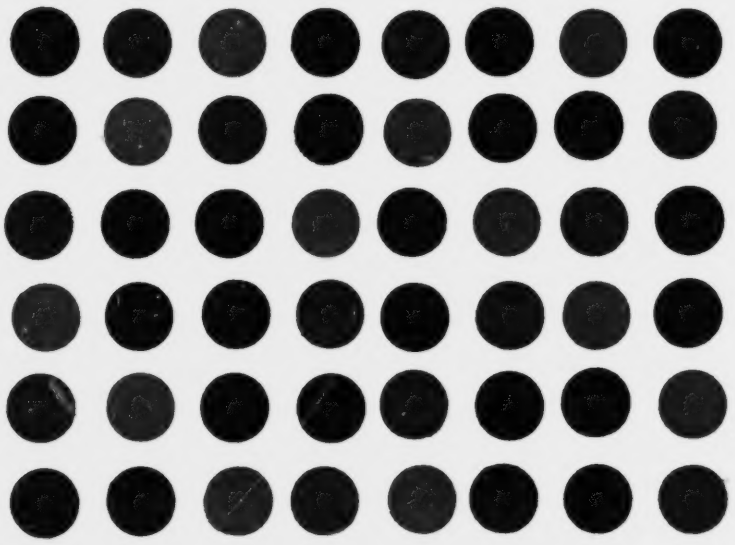

Figure 1

vert rouge noir mauve noir vert mauve rouge

mauve vert rouge noir mauve rouge vert noir

rouge noir mauve vert rouge mauve noir vert

noir mauve vert rouge vert noir mauve rouge

mauve noir rouge vert mauve rouge noir vert

noir rouge vert mauve noir vert rouge mauve

Figure 2

purple green red black green black red purple

black red green purple red purple black green

green purple black red purple red green black

red black purple green black green red purple

green red black purple green black purple red

purple black red green red purple black green

Figure 3

OE-BR

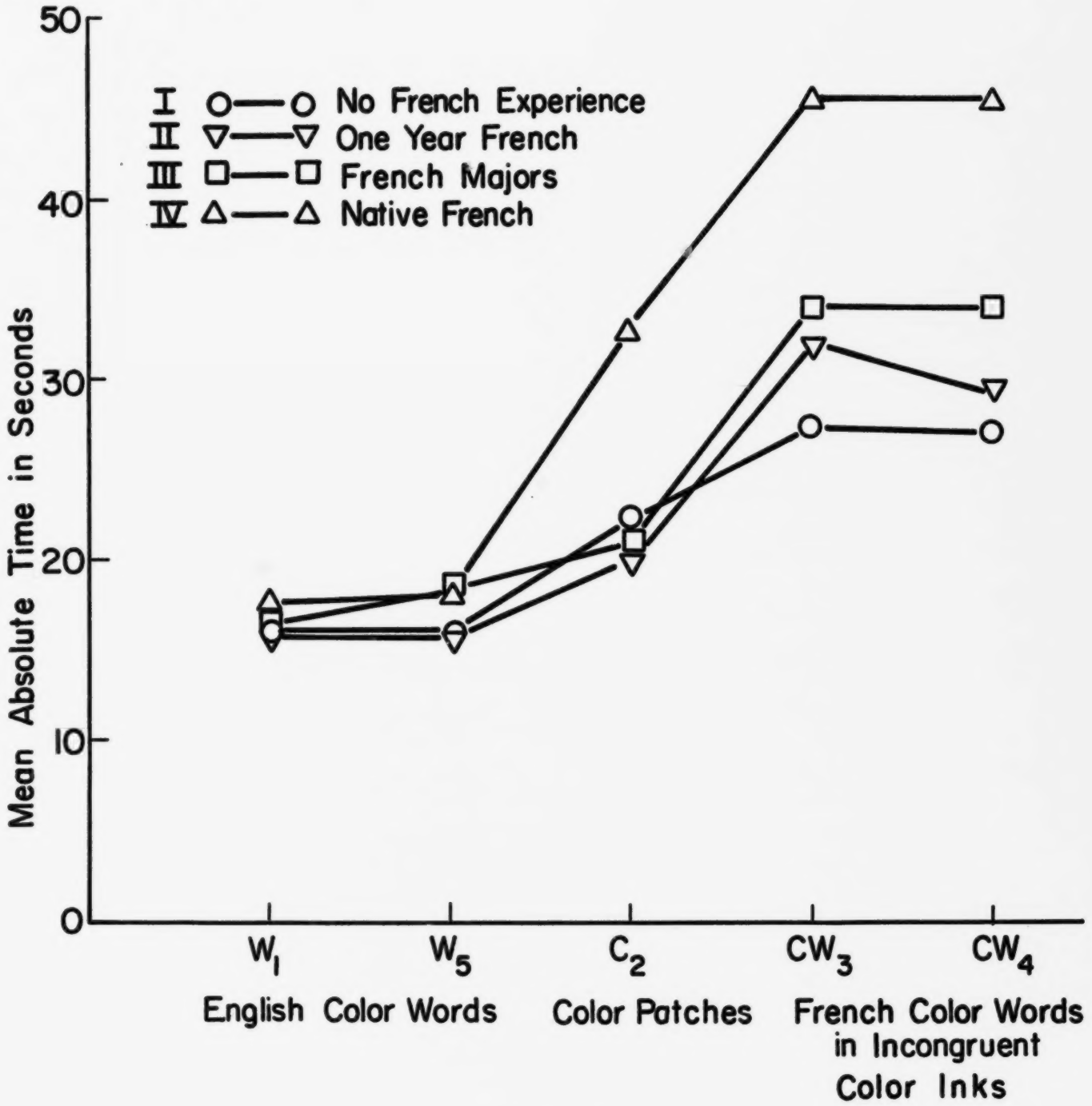

Figure 4